

WHAT IS CLAIMED IS:

1. A semiconductor device comprising:  
a semiconductor substrate, and  
a circuit element using an insulating film formed  
5 on said semiconductor substrate,  
said insulating film containing a silicon compound  
containing at least one element selected from the group  
consisting of an oxygen and a nitrogen, and a metal  
compound containing a metal other than silicon and at  
10 least one element selected from the group consisting of  
an oxygen and a nitrogen, nano-crystals being formed in  
said insulating film, the size of said nano-crystal  
being small enough to permit observation of a  
polycrystalline ring as a diffraction image when an  
15 electron beam having a beam diameter of the nanometer  
order is incident in parallel to said insulating film  
surface.
2. The semiconductor device according to claim 1,  
wherein said a silicon compound is a compound selected  
20 from the group consisting of a silicon oxide, a silicon  
nitride, and a silicon oxynitride.
3. The semiconductor device according to claim 1,  
wherein said nano-crystal grains are made of said metal  
compound.
- 25 4. The semiconductor device according to claim 2,  
wherein said nano-crystal grains are made of an oxide,  
a nitride or an oxynitride of a metal other than

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silicon.

5. The semiconductor device according to claim 1,  
wherein said nano-crystals grains has a diameter  
falling within a range of between 1 nm and 10 nm.

5. The semiconductor device according to claim 1,  
wherein said insulating film has a thickness falling  
within a range of between 3 nm and 20 nm.

7. The semiconductor device according to claim 1,  
wherein an oxynitride film is formed between said  
semiconductor substrate and said insulating film.

8. The semiconductor device according to claim 1,  
wherein said metals other than silicon is at least one  
metal selected from the group consisting of Ti, Ta, Y,  
Al, Zr, La, Hf, Nb and elements of lanthanum series.

15. The semiconductor device according to claim 1,  
wherein said functional element is a MOSFET, and said  
insulating film is a gate insulating film of said  
MOSFET.

10. The semiconductor device according to claim 1,  
wherein said nano-crystals being formed in said  
insulating film, the size of the largest nano-crystal  
grain in said insulating film being not larger than the  
thickness of said insulating film.

25. The semiconductor device according to  
claim 10, wherein the size in the thickness direction  
of said insulating film of the largest nano-crystal  
grain formed in said insulating film is substantially

equal to the thickness of said insulating film.

12. The semiconductor device according to claim 1,  
wherein a part of the periphery of at least one of said  
nano-crystals being positioned within a distance of  
5 0.7 nm from the interface of said insulating film.

13. The semiconductor device according to claim 1,  
wherein said insulating film is a mixed film containing  
said silicon compound and said metal compound.

14. A method of manufacturing a semiconductor  
10 device according to claim 1, comprising:

forming an insulating film containing a silicon  
compound containing at least one element selected from  
the group consisting of an oxygen and a nitrogen, and  
a metal compound containing a metal other than silicon  
15 and at least one element selected from the group  
consisting of an oxygen and a nitrogen, on a  
semiconductor substrate under temperatures at which  
crystallization does not take place; and

20 applying a heat treatment to precipitate a nano-  
crystalline metal oxide within said mixed film.

15. A method of manufacturing a semiconductor  
device, comprising:

25 forming insulating film being a mixed film  
including a silicon compound containing at least one  
element selected from the group consisting of an oxygen  
and a nitrogen, and a metal compound containing a metal  
other than silicon and at least one element selected

from the group consisting of an oxygen and a nitrogen  
on a semiconductor substrate under temperatures at  
which crystallization does not take place; and

5 applying a heat treatment to precipitate a nano-  
crystalline metal oxide within said mixed film.